

A cross check on Docdb 163

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Introduction

Some numbers re cosmic muons on our LArTPC.

This is an alternative approach to calculating the rates of cosmic muons in a cylindrical surface LAr vessel. It differs from the approach adopted in Docdb 163. In the present approach, I estimate the number of rays incident on the detector within the appropriate time window and the number of wires each ray passes to derive the total number of hits. This approach allows me to account for the energy spectrum of the cosmic muons and does not rely on assumptions about the readout resolution.

In Docdb 160, it is shown that the total rate of cosmic muons entering a cylinder with height = diameter = d is $R \times \pi^2 \times d^2/4$. (Note that this is π times the rate $dN/d\Omega$ straight down.) Consider Kirk's cylinder of height 40 meters and diameter 40 meters (which by the way has about 70 ktonnes of Argon). The rate of muons entering the tank with energy > 1 GeV (more than 5 meters path length in the tank) is $70 \times \pi^2 \times 400$ per second = 275,000 per second.

The portion of any cosmic muon track whose ionization reaches a readout wire between the beam spill time and the maximum drift time, t_{\max} , after the spill, will generate valid data. This means, for example, that a cosmic ray track that passes near the cathode any time between t_{\max} *before* the beam spill and the beam spill time will be recorded; likewise a muon that passes near the readout plane any time between the beam spill and t_{\max} *after* the spill will also be recorded. The result is that the number of tracks detected is indeed the number of tracks that cross the drift region during a time of duration t_{\max} - though the valid time wrt the spill varies across the gap. At 275,000 rays per second, there will be 825 muons detected in the detector volume if we have a 3 millisecond drift time.

How many 'hits' do these tracks generate, recognizing that a 'hit' has (at least) three parameters; one is the wire involved, the second is the time, and a third is the effective pathlength in the drift direction. Tracks at large angles to the plane of the readout wires will have quite large effective pathlength in the drift direction - of order the wire spacing.

Four effects beyond the TPC geometry affect the number of wires involved in each track. One is that the path length in the argon is limited by the energy of

the entering ray; the ionization loss is about 200 MeV/m and it takes at least 8 GeV to go across the entire detector. A second is that the rays are more vertical than horizontal; for a TPC with essentially vertical wires, this reduces the number of wires crossed by the tracks. For an angle of 30° from the zenith, the horizontal distance travelled is $1/2$ the total distance. A third effect is that rays which enter from the top unless they enter right at the periphery can not pass by every wire in a plane; the same effect operates for rays which enter from the sides (except for \sim horizontal rays). A fourth effect comes from rays whose direction is such that only part of their path is consistent with beam timing. An example is a track crossing from the anode (readout) towards the cathode which passes the anode 3 milliseconds after the spill; the electrons from the section of track away from the anode will drift in too late to be considered valid.

I now consider the first three of these effects in calculating the total number of hits. If we take a typical energy as 3 GeV (equivalent to a path length of 15 m = 3000 wires) and a typical angle from the vertical as 30° , the typical number of wires involved in a track will be $3,000/2 \times 2/\pi \approx 1000$, where the factor of $2/\pi$ comes from the azimuthal projection. (Note I have taken no credit for the fourth effect above.) The total number of hits in one co-ordinate is then $825 \times 1000 \approx 10^6$. This is spread over 50,000 wires (the total number of wires of each co-ordinate) and implies 20 hits/wire per 3 millisecond readout interval. These hits have several effects. As far as the data acquisition system is concerned, these hits are manageable. The data acquisition is designed to be able to record every digitizing (7.5×10^3 400 ns samples per 3 milliseconds) for all wires each spill. If one wanted to record only data above threshold, each hit gives about 30 digitizings (looking at the Icarus waveforms); one would then record 600 digitizings per wire per spill, a factor of 12 reduction... and a system where the hit centroid is found directly would have a further reduction of about 10 in data volume. (The factor 10 because each hit would require a time, a spread and a pulse-height while in the data above threshold, only the first sample requires a time and the spread is calculated from the samples.)

As far as a cosmic ray obscuring a genuine interaction, the chance of losing the vertex region in one co-ordinate depends on the two-hit resolution. If this is 1 cm, then the chance per co-ordinate is $20 \text{ cm}/5 \text{ m} = 4\%$, and the chance to lose it in 2 planes is 1.6×10^{-4} .

As far as pattern recognition, an issue that Kirk has emphasized from the beginning, I think it is clear that the pattern recognition cannot start by trying to form space points between two co-ordinates but needs to form lines (planes) in each co-ordinate independently (as one does by eye).